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Biofuels adoption in Nigeria: Attaining a balance in the food, fuel, feed and fibre objectives

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ABSTRACT

The drive towards economic development in Nigeria brings about the pursuit of many competing objectives whose attainments depend on limited resources. Biofuels adoption has been set as an important path, among other options, for pursuing economic growth and development for the country. The Federal Government of Nigeria (FGN) is currently promoting the production, processing and utilization of biofuels in the transport and energy sectors. The article examines biofuels adoption in Nigeria vis-à-vis the attainment of a balance in the food, fuel, feed and fibre objectives. Crops already profiled as preferred sources of feedstock for the primary biofuels production are also crucial for food, feed and fibre. The resources needed for producing these crops are limited, hence the need for a balance. This paper derived data from secondary sources including the Food and Agriculture Organization (FAO). The paper explores some aspects of biofuels sustainability and present recommendations for attaining a balance in the multiple objectives for attaining socioeconomic development.

Contents

1. Introduction

Energy is a critical factor in the pursuits of socioeconomic growth and development objectives of any nation. Energy is required for driving activities in the various sectors of the economy. There is also a linkage between energy supply and consumption, and meeting the food, fuel, feed, and fibre targets which in turn determine the aggregate contribution of agriculture and other sectors to the national gross domestic product (GDP). Various studies have attested to the strong link between energy consumption and socioeconomic development. Kebede et al. [1] posited that there is a direct relationship between energy use and technological development on one hand and economic growth on the other. Yildirim et al. [2] established the link between economic

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growth and energy consumption in the USA. The economic growth and development witnessed in China, India, Austria, Japan, and the United Kingdom have also been reported to lead to increase in energy consumption [3–5].

Karekezi [6] quoting an earlier report indicated that the rationing of electricity in Ethiopia, Kenya, Malawi, Nigeria and Tanzania impacted adversely these economies. The low energy consumption in Sub-Saharan Africa (SSA) accounts largely for why the GDP in these countries are among the lowest in the world [6]. The energy consumption and economic growth linkage re-enforces the need to gear up energy generation and consumption in an economy like Nigeria struggling to take off. Esso's [7] study of seven African countries including Nigeria re-enacted the fact that energy consumption and economic growth are co-integrated. This implies, to ensure the growth of the Nigerian economy is not impeded, concerted effort in policy and investment must be channelled towards ensuring stable energy consumption.

Access to energy at both the urban and rural sector of the Nigerian economy has been a recurring issue. Nigeria still depends on imported refined petroleum products for meeting the local consumption for transport, electricity generation and powering other activities. The decline in the local refining capacity as the nation's refineries age has led to the dependence on import for over 70% of the refined petroleum products consumed in Nigeria [8]. Recent industrial and civil crisis relating to the hike in prices of petroleum products, resulting from the removal of subsidies on imported refined petroleum products is an indicator of how dire the energy situation is in Nigeria [9]. The energy related crisis also is also telling on the nation's revenue profile as the financial burden of subsiding petroleum products increase every year. With the decline in industrial and agricultural production, partly accounted for by the energy shortage, Nigeria now depend largely on import for meeting food, feed, and fibre demands. Like in other countries with food security concern in West Africa, Nigeria import food to meet the shortfall in demand that local production cannot fulfil [10]. The trend in imports has been on the increase, making Nigeria a net importer of food and other products.

The overall impact of unstable supply of imported petroleum products, unstable prices tied to prices of crude oil internationally constitute further constraint on an economy with increasing unemployment, poverty rate, among other socio-economic indicators. The introduction of the biofuel policy in 2007 was set to provide an alternative path through agriculture to solving energy and related socioeconomic problems. Facing the obvious energy challenges, Nigeria, which is endowed with the conventional and renewable energy resources, must harness these resources to meet the fuel requirement for socioeconomic growth and development.

As the Federal Government of Nigeria (FGN) pushes the agenda of growing the economy through biofuels adoption, this paper explores some aspects of biofuels sustainability and how to attain a balance in and securing the supply of food, fuel, feed and fibre. The paper offers interpretations on the link between the objectives and how the advancement of biofuels can help in attaining the needed balance.

The data used in this paper were mainly derived from the Food and Agriculture Organisation (FAO) crop production and food balance sheet database. Data on water footprints for biofuels crops production, water footprint per energy and per litre of biofuel were sourced from Mekonnen and Hoekstra [11]. The paper is based on basic statistical analysis of secondary data on the crop production and land use.

2. Situating the food, feed, fuel and fibre objectives in the Nigerian biofuel policy

The advancement in the biofuel development and adoption in Nigeria is hinged on the directive – Automotive Biomass Programme for Nigeria – and the subsequent Nigerian Biofuel Policy and Incentives [12]. The directive and policy were put in place to promote biofuel utilization through seeding of the market through importation of refined ethanol from Brazil and promoting local production [13,14]. So far, no study exists showing there is a strategy in place to attain a synergy between food, feed, fuel and fibre objectives in Nigeria.

The biofuel policy identify and classified biomass as renewable raw materials from agriculture including trees, crops, plants, fibre, cellulose based materials, industrial wastes and biodegradable municipal solid wastes [12]. A further description of biofuel feedstock in the policy document include cassava, sugarcane, oil palm, jatropha, cellulose based materials and other crops as may be approved by a commission governing biofuel utilization in Nigeria. This broad categorization includes the sources of food, feed, fuel and fibre (for textile). Since the crops classified and being promoted for biofuel production are also used as food, feed or fibre, it is expected that the use of these crops for biofuel does not affect the attainment of other equally important objectives. In this scenario, there is bound to be conflict between food, fuel, fibre and feed, as these compete for the utilization of land, water, labour and other factors of production. Ohimain [15] had pointed out the obvious gap in the Nigerian biofuel policy and incentives of 2007 as it failed to address the potential food versus fuel conflicts. There is also the possibility of feed versus fuel, fibre versus fuel conflicts.

As the biofuels subsector in Nigeria evolves, it is crucial that the omitted goal of attaining a balance in the food, feed, fuel and fibre objective be included in the subsequent review of the Nigerian Biofuel Policy and other legislations that will be put in place to promote biofuel development and utilization. Though the current biofuels policy recognized that some food, feed, and fibre crops are biofuels feedstock, the policy was designed as mainly pursuing biofuels development goal in isolation to other objectives. The reworking of the biofuel policy must extend equally important incentives such as tax relief and import duty waiver; meant for facilitating the production of the crops classified as biomass or feedstock to crops devoted to other objectives.

3. Making biofuels sustainable in Nigeria

The advancements in biofuels adoption are not without fervent debates on the sustainability of fuels sourced from biomass. Amigun et al. [16] appraised the sustainability of biofuels in Africa on the premise of food versus fuel, land use and tenure security, climate change and environment, poverty impact and gender equality. The paper drew a conclusion on the need to adopt along with biofuels development, practices, process and technologies that can improve efficiency, reduce energy and water requirements for biofuels production. Janssen and Rutz [17] assessing biofuels development in Latin America vis-à-vis risks and opportunities concluded that environmental and social aspects are crucial for sustainability.

Specific issues about biofuels sustainability have also been assessed by other authors. Yang et al. [18] examined the land and water requirements for biofuel production in China and concluded that the pursuit of the current biofuel development path for the country will impact significantly food supply, trade and the environment. Owing to the link between fuel, food, feed and fibre, the production of one may influence the price of the other. Zhang et al. [19] identified a potential influence on the short-run prices of agricultural commodity as the global production of ethanol increased.

In summing the arguments on biofuels sustainability, von Braun [20] proposed a conceptual framework bordering on political, economic and environment as essential domains for assessing biofuels.

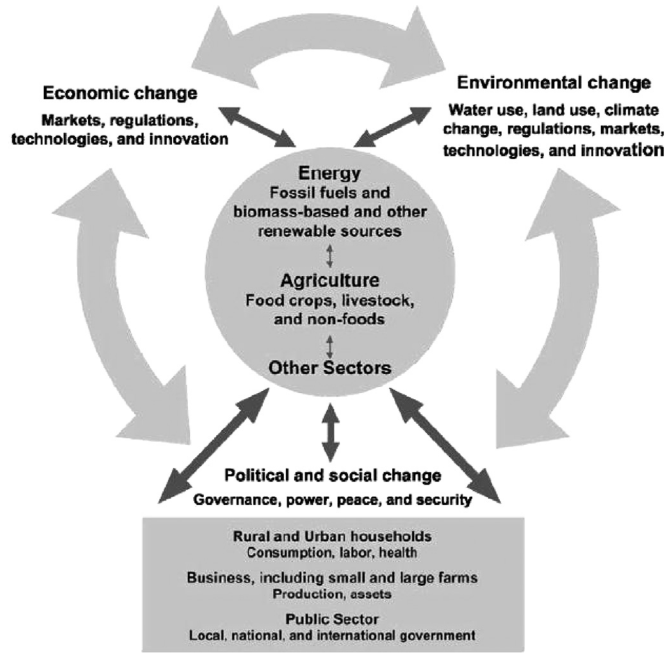

Fig. 1. Conceptual framework for assessing biofuels sustainability.
Source: von Braun [20].

Fig. 1 details the elements of von Braun's conceptual framework for assessing biofuel sustainability. This proposition argued for considering broader perspectives in assessing biofuels' issues rather than the use of simple yardstick of trade-offs between food and fuel. von Braun's proposition is hinged on the existence of an interaction between the three domains when agriculture and energy are linked through biofuels.

Biofuels adoption, promotion and utilization in Nigeria does not necessarily lead to, and should not be about trade-offs between fuel and food, or between other objectives such as fibre, feed, ecosystem preservation or biodiversity conservation. The primary biofuels, including fuelwood, charcoal, palm kernel shells, palm-oil wastes, sawmill wastes and cow dung still constitute a large proportion of energy source for cooking in Nigeria [14]. The adoption of first and second generations' biofuels provide solutions to environmental, economic and social problems such as deforestation, pollution and health risks associated with the use of the primary forms of biofuel, which are predominant in Nigeria.

Considering biofuels sustainability in Nigeria, the scientific arguments – environmental, technological, political, social and economic are no longer about if biofuels are acceptable but on how to guarantee and stabilize gains from the adoption of biofuels; maximize biofuels output per investment in feedstocks, processing technologies and distribution networks; optimize natural resource use in a biofuels' revolution; minimize environmental, social and economic impacts and develop efficient frameworks for meeting biofuels targets. The increasing adoption, promotion and investment into biofuels development have become irreversible owing to political, economic, environmental and social factors driving the biofuels revolution [14,21–23]. Based on these factors, it is obvious that the real concern is to ensure a sustainable biofuels' era.

As much as the three main domains proposed by von Braun [20] for assessing biofuels sustainability are tenable, the policy formulations and discussions about biofuels in Nigeria must transcend the meeting points between agriculture and energy on the political, economic and environmental domains. The emerging pivot for pushing for sustainable biofuels utilization is allowing for a balance in the pursuits of the multiple, competing and or complementing objectives. The pursuit of the food, fuel, feed and fibre objective can be seen beyond the competition for available arable lands, water resources, labour and capital. In avoiding conflict in the pursuits of these multiple goals, interlinking between the objectives through a lateral integration that allows for by-products from one enterprise to be transferred to another will enhance productivity. A good example is ensuring that the by-products from cassava production and processing that have for some time been considered as waste and disposed of, constituting environmental pollution and ecosystem destruction can be channelled into feed for livestock in an integrated production system. The interlink between agriculture and new energy sources – biofuels necessitates ensuring optimal sharing and allocation of the limited resources such as arable land and water. There is also the need to ensure the transfer of by-products from one enterprise to the other. This is the required paradigm shift to ensure biofuels sustainability.

3.1. Social concern

The social concerns within the tripod for sustainability regarding biofuels adoption in Nigeria is to ensure the attainment of the full range of social objectives as listed by Abila [14], including poverty reduction, employment creation, ensuring access to fuel, electricity and engendering rural development. The five decades of the exploration of petroleum can be adjudged to have failed in the social angle; hence, the emergence of a thriving biofuels subsector must ensure the non-repetition of such a trend. Decentralizing the entire value chain of biofuels production and allowing a fair participation of even the small scale farmers is a crucial policy for ensuring social sustainability. In this regard, the push for the maximization of the production of feedstocks must not lead to the takeover of small farm holdings by the bigger large-scale investors. The out-grower scheme listed in the biofuels policy for Nigeria, which is to facilitate arrangement between farmers and biofuels mill companies in the cultivation of feedstocks must be revised to ensure small scale and female farmers are not disenfranchised. Cooperative farming arrangements that will allow the farmers with small landholdings to pool and annex their farmlands to meet the basic farm size requirement for qualification under the out grower scheme must be put in place.

3.2. Economic concern

Making economic growth resulting from the emerging biofuels' subsector stable and efficient is crucial for sustainability. Though the Automotive Biomass Programme for Nigeria [12] was set out to facilitate the advancement of biofuels, the implementation of the policy needs to incorporate building and maintaining the natural and man-made assets for driving the biofuel revolution. Ensuring economic sustainability of the biofuel development in Nigeria necessitate allowing for critical resources such as land, labour, capital to be available for other important sectors. The growth of the biofuel economy must not be at the expense of manufacturing, transport, health, or other sectors of the economy. The growth of the biofuels sector must equally stimulate progress in other related sectors. Harnessing the default linkage between biofuels production and other sectors is necessary. The biofuels developments interventions and incentives must be well situated within the bigger economic development plans relating to other sectors.

3.3. Ecological concern

The possible threat to ecosystem, biodiversity and biological resources has been a main issue in the contention over biofuels sustainability. Nigeria's primary forest resources and fragile

ecosystems need not be further threatened by biofuels development. The opportunity for the full utilization of the existing underutilized agricultural lands and curbing major ecological challenges such as charcoal production and deforestation should be an intrinsic aspect of the biofuels development policy. The provisioning of biofuels as alternatives for livelihoods and meeting the basic energy requirement – lighting and cooking is pivotal as the Nigerian economy enters into a green energy era.

4. Trends in food, fuel, feed and fibre situation in Nigeria

Nigeria has been a net importer of processed and unprocessed foods since the discovery of petroleum led to prioritizing oil and gas as the major revenue source and mainstay of the economy to the detriment of agriculture and agro-allied productions and processing. FAO [24] reported that wheat and milled rice top Nigeria's staple food import apart from other processed products such as tallow, palm oil, milk, malt and margarine. The value of Nigeria's top twenty import agricultural commodities stood at $3.7 billion for 2009. This is an indication of the inability to meet consumption of key staples from domestic production. Efforts in the last decades have been on increasing local production of staple crops such as rice; accounting for the highest foreign exchange utilization and a huge drain on the foreign reserve, and tilting the trade balance towards the negative.

von Braun [25] analysis of the global food situation showed that there was marked increase in the food consumption in a number of developing countries from 1990 to 2005. Within the same period, Nigeria did not witness any marked changed in the consumption of high valued food products such as meat, milk, fish, fruits and vegetables as reported by the same study. Nigeria continues to struggle with the food crisis, chief among which is high inflation on food prices. The prevailing food concern in Nigeria has been a symptom of the declining local production, which is exacerbated by the energy crisis facing the country. Curbing the spiralling inflation on food prices requires ensuring affordable and profitable local production and an efficient cheaper distribution of the imported and locally produced food products. The cost of distribution of food products between the originating points to the consumption points depends largely on fuel prices.

The tie between food and fuel prices has increasingly become entrenched with Nigeria's dependence on imports for meeting local fuel consumption. Hike in the price of crude oil internationally translate into an increase in the cost of everything, particularly food with no visible safety net such as subsidizing the transport and haulage for food products. The lack of cheaper alternative fuelling options for heavy-duty transport, other than expensive diesel, makes the drive towards developing locally produced biodiesel a priority for curbing food crisis. The entire value chain of food production through processing to distribution requires diesel, the most expensive petroleum product in Nigeria. Maconachie et al. [26] reported that the prices per litre of diesel for the years 2006, 2007 and 2008 were $0.92, $0.95, and $0.94 respectively. In the same period, the price of petrol was reported to be $0.63, $0.61, and $0.60, while the price of kerosene was reported to be $0.75, $0.78, and $0.77. These figures shows the prices of diesel far outshot other petroleum products.

The fuel consumption in Nigeria has also been import dependent. Jesuleye et al. [27] indicated an increasing importation of refined petroleum products as the refining capacity of the local refineries declined. This indicates the petroleum products supply for meeting local fuel consumption for transport, cooking, lighting and electricity generation, which represent the topmost demand for petroleum products – diesel, petrol, and kerosene – increasingly depend on import. Apart from the shortfall in refined conventional fuels, Nigeria is also about 5 billion l per annum short of the ethanol required for meeting the current mandatory E10 petrol blending [13]. The fuel situation is further compounded by the persisting inability of the country to generate electricity for household and industrial need. With the current rate of electricity generation in Nigeria hovering around 4000 MW, the inadequacy of this generation capacity get more glaring as the population increases. Abila [14] highlighted the dependence on primary biomass for basic energy requirements such as cooking on the account of the lack of the conventional and cleaner alternative. IEA [28] shows that electrification rate for Nigeria only covers about 47% of the country. This data only relates to the electrification infrastructure and does not provide the frequency and quality of the supply of electricity, which has been on the decline even in areas with installed transmission infrastructures. Most homes, businesses, public and private institutions have to resort to standalone electricity generation running on diesel or petrol.

The feed concern is also captured by the current shortfall in meeting animal protein requirement for the country. FAO [24] data shows Nigeria still depend on import for meeting the requirement for meat, eggs, milk and other animal products. This indicates the inability of the country to meet the demand for animal products, particularly dairy products such as milk, and cheese from the local production.

Nigeria has the appropriate climatic, geological and hydrological conditions for the production of most fibres crops, but cotton has been the dominant crop. Bamboo, jute, hemp and other fibre crops grow very well in Nigeria, but these are not being produced at a commercial scale, nor has there been an obvious concerted effort devoted to their production at a large scale for deriving fibre raw-materials for meeting the local manufacturing demand or for export. Cotton, which has dominated the fibre sub-sector in Nigeria has witnessed spiral trend in the production since 1960. The five decades data for cotton production in Nigeria shows an up and down trend within each decade with the 1980s showing the lowest production of cotton lint when the country produced a mere 10,524 ton. Since the lowest record of 1985, cotton lint production has witnessed an unsteady growth. According to FAO [29], the cotton production in Nigeria peaked with 0.197 million - tons of cotton lint in 2006. The sharp drop in the production between 1992 and 1993 is in sync with the price of cotton lint that fell to about $873/ton in 1992 from the previous year value of $1680/ton. The production also rose as the price picked up until the drop in export volume from 2007 which was exacerbates by the absence of local absorption for the lint produced with the near collapse of the textile industries in Nigeria. Fig. 2 shows the unstable production of major crops over five decades. Abila [14] compared the ranking of Nigeria on productivity per hectare devoted to the production of major biofuels crops. For most of these crops, Nigeria ranked lower in productivity as compared to the country's higher rank in terms of the nominal output and land area cultivated. For cotton, Nigeria ranked ninth in terms of land area cultivated, but ranked eighteenth in terms of productivity per land use when compared to other major producers globally. Increasing the productivity per land, labour, capital and other resources devoted to the production of cotton lint and by implication, cotton seed, is an essential goal that must come along with the pursuits of increasing nominal output.

The Federal Government of Nigeria (FGN) has set forth a target of tripling the current production level for cotton lint and cotton seed by 2015. This target aims to engender local production of cotton lint and cotton seed for the purposes of reviving the nearly extinct textile industry, and stimulating production of allied industries such as the vegetable oil production. The drive for revamping the local cotton production is towards increasing the contribution of the fibre sub-sector to the agricultural component of the GDP which has been low for some time.

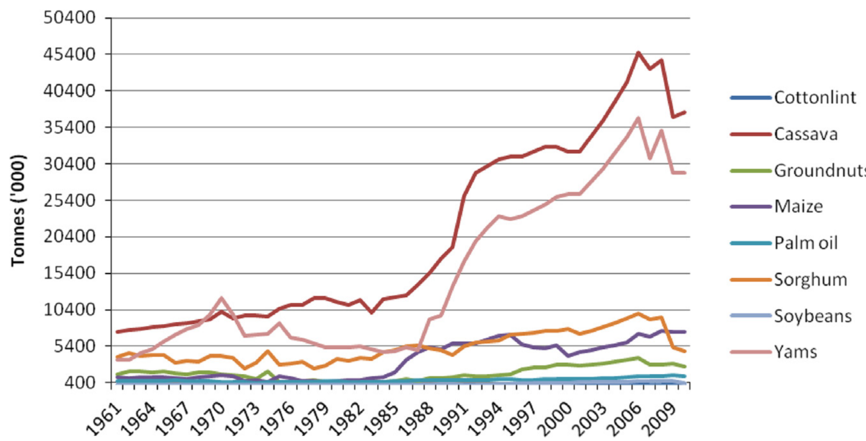

Fig. 2. Five decade trend in major crops production (tons) in Nigeria.
Data source: FAO [29].

Table 1
Nigeria's average production and productivity of major crops essential for meeting the four objectives from 2000 to 2009.
Source: adapted from FAOStat database on world crop production [24].

Crop	Average production (ton)	Average area cultivated (ha)	Productivity per hectare (ton)	Global productivity per hectare	Target productivity increase to meet global average
Cassava	3,854,293	3,547,851	10.86	11.41	0.55
Maize	5,900,784	3,529,086	1.67	4.75	3.08
Green maize	658,793	199,815	3.29	8.09	4.80
Cotton seed	472,948	549,680	0.86	1.94	1.08
Sesame	93,602	211,959	0.44	0.48	0.04
Groundnut	3,071,837	2,121,135	1.45	1.55	0.10
Soyabean	526,586	578,753	0.91	2.31	1.40
Coconut	195,686	38,700	5.06	5.04	−0.02[a]
Sugarcane	1,002,275	47,095	21.28	65.65	44.37
Oil palm	8,485,200	3,203,500	2.65	13.38	10.73
Rice	3,380,459	2,289,920	1.48	4.08	2.60
Millet	6,738,989	4,707,960	1.43	0.85	−0.58[a]
Sorghum	8,161,079	6,889,473	1.19	1.37	0.18
Cashew	581,160	298,500	1.95	0.62	−1.33[a]
Karite nuts	417,498	251,932	1.66	1.84	0.18
Mellon	416,643	638,754	0.65	0.65	0.0
S. potatoes	2,853,182	957,679	2.98	13.61	10.63
Potatoes	753,478	243,700	3.09	16.91	13.82
Yam	30,778,200	2,871,901	10.72	10.28	−0.44[a]

S. potatoes – sweet potatoes.

[a] The Nigerian productivity exceed the global rate.

5. Situation of the major crops between 2000 and 2009

The pursuit of a balance in the food, feed, fuel and fibre objectives must rest on ensuring a stable and efficient production of the major essential crops. Though there is enough land and rainfall for the production of most of these crops, the productivity per hectare and other resource devoted the production of these crops is still currently low. Table 1 shows the average production and productivity per land area devoted to the cultivation of some of the major crops in Nigeria, in comparison to the global productivity. The figures in the table are estimated ten years average; from year 2000 to 2009. For much of these crops, it is obvious that Nigeria still lags behind the global productivity per hectare cultivated. For all the 19 crops profiled, only coconut, millet and cashew are currently produced with productivity per hectare above the global average. Of the three crops that can be considered as faring well in terms of productivity, only millet is produced largely for its commercial or subsistence purpose. Coconut and cashew are currently grown as marginal crops, not consciously cultivated for the purpose of deriving subsistence or sale for income. Increasing the productivity per hectare in order to attain a balance in the food, feed, fuel and fibre will also require addressing issues that currently account for the low productivity such as decreasing soil fertility and the low use of innovations and inputs for soil improvement. Promoting and implementing land management practices that will sustain soil fertility as well as increasing access to affordable technology for the production of these crops should feature in the policy and incentives already in place for encouraging production.

The current agricultural production policy must also provide a target in productivity per land and other resources devoted to the production of these crops, beyond stating a target for increasing

nominal production rate. From Table 1, the wide margin between the productivity per hectare for Nigeria and the global rate is obvious for sugarcane, oil palm, sweet potatoes and potatoes. The wide margins can be explained in that these crops are not produced as main commercial or subsistent commodities. Most farmers grow these crops as marginal crops for secondary purpose of additional income or subsistence. The increasing relevance of these crops for food, feed and fuel should stimulate the intensification of the production towards enhancing productivity. The trend is changing for oil palm as the global demand is on the increase and subsequently changing the fortunes of the crop. Most oil palm plantations that gave Nigeria the top position in the production of the crop in the sixties that have gone moribund are being revitalized.

6. Current utilization balance sheet for the major crops

An individual crop item can be used for more than one purpose. Different parts and products derivable from a crop can serve differing purposes. A good example is the cotton which is produced mainly for the lint but the seeds extracted from the lint are further used for oil extraction for food or fuel, while the residual cake from the oil extraction is a component for producing feed concentrates for livestock. In this scenario, the pursuits of increasing the production of a particularly crop by default will lead to increasing the supply of raw materials for meeting a combination of two or more of the food, feed, fuel, fibre or other objectives. Table 2 shows the current utilization balance of the major crops produced in Nigeria. The figures in the table depict the average estimate for 10 years – between 2000 and 2009. From the table, it is obvious that even with the demand for the products and parts of a crop in meeting different needs, some of the products are still wasted due to the inability to absorb these for the required needs, the occasional glut situation, the logistics and distribution impediments – particularly in situations where crop products and parts are produced but there are no sufficient haulage facilities to convey them to the market or point of demand. In the face of an increasing expansion of the utilization of some of these crops for more than the current utilizations, to include biofuels production and as industrial raw materials, government policy on biofuel production and related interventions must ensure a near total utilization of the crops produced. Ensuring that there is a market for current production is crucial for stabilizing production overtime and to avoid occasional scarcity that follows periodic gluts.

The current scenario of the utilizations of crops such as cassava, millet, maize, groundnut and sorghum with huge proportion of the production still wasted yearly gives credence to the timeliness and usefulness of the policy of the Federal Government of Nigeria promoting biofuels production, processing and utilization across the country. The biofuel policy, if fully implemented will provide for the full absorption of the yearly production of these crops. Along with other policy interventions such as mopping excess production of crops for stocking Federal Government silos and food reserve banks, facilitating the utilization of these crops for other equally essential objectives will serve the purpose of stabilizing prices both in and out of the production season. There is a recurrent scenario where prices shot up during the out of season, but the prices fall far below the point where farmers can breakeven during the in-season. The strong link between the absorption of the production and price stability is crucial for ensuring sustainable production at the medium and long term. By extension, one can posit that this is also pivotal for the success of policy interventions aimed at increasing nominal production, productivity of resource use and the adoption of best practices, innovation and technologies.

Table 2
Major crop's utilization balance sheet for Nigeria – average from 2000 to 2009.
Source: adapted from FAOStat database on world crop production [24].

Crop	Products/ parts	Current major utilization	Average production (ton)	Average utilization as food (ton)	Average utilization as feed (ton)	Average utilization as other (ton)	Average waste (ton)	Percentage of waste to production (%)
Cassava	Roots	Food+Feed+Other	38,542,930	15,982,413	18,042,446	186	4,511,437	11.70
Maize	Seed	Feed+Food+Other	5,900,784	3,212,408	1,794,162	19,730	666,438	11.29
Cotton	Lint	Fibre	171,000	–	–	158,866	–	–
	Seed	Food+Feed	255,782	–	–	90,287	13,165	5.15
	Seed cake	Feed	57,105	–	48,743	–	–	–
	Seed oil	Food	20,557	20,980	–	–	–	–
Sesame	Seed	Food	92,631	2260	–	–	11,549	12.47
	Seed cake	Feed	9180	–	9180	–	–	–
	Seed oil	Food	6120	6117	–	–	–	–
Groundnut	Cake	Feed+Food	686,100	–	686,393	–	–	–
	Oil	Food	566,800	563,229	–	–	–	–
	In shell	Food+Other	3,071,837	426,243	–	501,429	210,081	6.84
	Shelled	Food+Other	2,150,286	298,370	–	351,000	147,056	6.84
Soyabean	Cake	Feed	10,400	–	33,589	–	–	–
	Oil	Food	2340	3418		–	–	–
	Seed	Food+Feed	526,586	385,013	53,203	–	53,203	10.10
Coconut	Seed	Food+Feed	199,920	88,507	6559	–	13,995	7.00
Sugarcane	Stem	Food	1,003,107	136,651	–	273,000	–	–
Oil palm	Palm oil	Food+Other	1,135,500	735,500	–	635,912	42,513	3.74
	Kernel cake	Feed	538,573	–	459,633	–	–	–
	Kernel oil	Other	495,487	495,901	–	–	–	–
	Kernels	Feed+Other	1,083,079	–	–	–	–	–
Rice	Milled	Food	2,254,766	2,992,802	–	–	241,952	10.73
	Paddy	Food	3,380,459	4,486,959	–	–	362,746	10.73
Millet	Seed	Food+Other	6,738,989	4,815,277	1,047,868	–	796,850	11.82
Sorghum	Seed	Food+Other	8,161,079	5,648,612	1,271,321	–	962,825	11.80

7. Resource requirements for attaining food, fuel, feed and fibre objectives

The food, fuel (biofuel), feed and fibre are agriculture related objectives which require access to land and water for their production. Spiertz and Ewert [30] highlighted the dependence of production of food, feed and fuel objectives on the critical resources of land, freshwater, and biodiversity. von Braun [20] also outlined the resources critical for a nation to have the potential for biofuel production to include availability of water resources and availability of arable land. The global profiling of countries with high and promising biofuel production capacity based on the availability of water and arable land include Nigeria [31]. Table 3 presents water and land use situation of major biofuels crops which are also cultivated for food, feed, and fibre. The water footprints for the biofuels crops production and the respective water footprints for energy and biofuels production are based on the estimates made by Mekonnen and Hoekstra [11].

The water footprint concept was introduced initially by Hoeskstra [32]. It has been deployed for assessing biofuels production water footprint for various countries and region to help analyse human water consumption in relation to the available global freshwater [18,33]. Hoekstra et al. [34] defined water footprint as the total volume of freshwater that is used in the production of a product. The figures for the water footprints are the aggregates for the blue, green and grey water footprints in cubic metre per ton of crop produced. The blue water footprint is the surface and ground water consumed during production of a good, the green is the rainwater used in the production of a product while the grey refers to the volume of freshwater needed to absorb the pollutant with respect to existing water quality [11].

From Table 3, cashew and sesame have the highest water footprint per ton of the crops produced. The crops being promoted for biofuels production in Nigeria, namely: cassava and sugarcane have water footprints that are not so high, 564 m^3/ton and 210 m^3/ton respectively. Though, the percentage water footprints of each biofuel crop to the national water footprint for crop production for Nigeria are so insignificant, considering the very low values, there may be an increase in the values as the demand for crops for biofuels production increase. The water footprint of the possible crops that can be cultivated towards biofuel production in Nigeria has implication for the Nigerian biofuel policy. As Nigeria strives towards local production of biofuels needed to meet the E10 blending rate for ethanol and D10 blending rate for biodiesel, emphasis must be on the crops with low water footprint per ton of crop produced and litre of biofuel produced.

The table also shows percentage land use for each crop to the total national arable and permanent land use for crop production in Nigeria. Sorghum has the highest value (20.1%), followed by millet (15.0%). Cassava and sugarcane currently occupies 9.8% and 0.1% of the arable and permanent land use in Nigeria. The expansion of land cultivation for meeting the biofuels requirements must take cognizance of the current level of land use of the crops of interest in relation to other crops for meeting the requirements for food, feed and fibre.

8. The linkage between biofuels adoption and the four objectives

The entire value-chains from the farm production to processing of the food, fuel, feed and fibre products require energy. The production of biofuels particularly at the farm level provides an alternative fuelling option for farm operations. Enhancing energy self-sufficiency for farms, particularly fuel for tractor operations, haulage, running generators for electricity used in processing and refrigeration will be a good cost saving option, for increasing productivity, increasing profit and reducing farm level emissions.

Though there might be a competition between food, fuel, feed and fibre objectives, it is expected that an efficient allocation of the required resources and designing an appropriate plan for implementing lateral integration of production will help in increasing

Table 3
The water and land use situation of major biofuels crops produced in Nigeria.
Source: Mekonnen and Hoekstra [11].

Crop	Biofuel yield (l/ton)[a]	Crop water footprint (m^3/ton)[b]	Total water footprint per unit of energy (m^3 per GJ of biofuel)[b]	Water footprint per litre of biofuels (litre of water per litre of biofuel)[b]	Percentage of hectarage to the total arable and permanent crop land use (%)	Possible combination of objective use
Ethanol crops						
Cassava	222	564	109	2538	9.8	Food+Fuel+Feed
Maize	428	1222	121	2855	11.6	Food+Fuel+Feed
Sugarcane	99	210	91	2107	0.1	Fuel+Food+Feed
Millet	–	4478	–	–	15.0	Food+Feed+Fuel
Sorghum	434	3048	300	7023	20.1	Food+Feed+Fuel
Potatoes	131	287	94	2192	0.5	Food+Feed+Fuel
Rice	434	1673	165	3855	6.4	Food+Fuel+Feed
Biodiesel crops						
Oil palm	213	1098	156	5166	9.3	Food+Fuel+Feed
Cotton seed	222	4029	547	18,134	1.6	Fibre+Food+Feed+Fuel
Sesame	–	9371	–		0.5	Food+Fuel+Feed
Groundnut	421	2782	200	6607	6.2	Food+Fuel+Feed
Soybeans	188	2145	343	11,397	1.6	Food+Fuel+Feed
Coconut	17	2687	4751	157,617	0.1	Food+Fuel+Fibre+Feed
Cashew	–	14,218	–	–	0.8	Food+Fuel+Feed
Mellon	–	5184	–	–	1.5	Food+Fuel+Feed

Water footprint for crop production for Nigeria (1996–2005) is 192 Gm^3/yr (Mekonnen and Hoekstra [11]).
CW = crop water.

[a] As reported by Mekonnen and Hoekstra [11], based on the density 0.789 kg/l for ethanol and 0.88 kg/l estimated by Alptekin and Canakci [35].

[b] Figures based the average data for crop production from 1996 to 2005.

productivity per resource utilized. This paper is premised on the assumption that based on the current concerns for food, fuel, feed, and fibre, the adoption and development of biofuels in Nigeria creates a unique avenue for creating a linkage for attaining balance between the objectives. This will help in attaining desired growth in each sub-sector and the required minimum contribution to
GDP, which will better reflect evenly distributed economic growth rather than a skewed growth accounted for by a few promising sectors.

Attaining a balance in the multiple objectives, which are as equally complementing and competing, can be achieved through integration, by channelling by-products or hitherto unutilized wastes from one objectives venture into another. By-products such as waste and compost will contribute to increasing the attainment of other objective ventures by improving the utility of constraint resources such as land and labour and offsetting the cost of capital such as fertilizer. In the scenarios where the objectives ventures cannot be paired or co-produced simultaneously, an arrangement for consecutive production planning bringing in additional resources at lower cost may be appropriate. A typical example can be producing food crops when they are better produced optimally rain fed, and switching to biofuel crops during the dry season or seasons of low rainfall for crops with low water footprint (less demand for rainfall). The scenario may have to be varied from the low rainfall regions of northern agro ecological zone to the high rainfall humid southern region.

The existing biofuel incentives and policies must go a little further to adjust the existing plans for the biofuel programs of the Federal Government and various other private and public entities to take cognizance of the need to attain balance in the multiple objectives. The growing population of Nigeria is a unique incentive as well as caution for taking a more analytical path which considers the element of growth in the population, and the attendant increase in the demand for the various objective ventures of food, feed, fibre, as well as the increasing constraints and possible conflicts between the objectives for the limited resources.

Fig. 3 shows a conceptual integration pathway for integrating biofuel production with the production of crops meant for meeting the food, feed, fuel and fibre objectives. The figure shows by-products and resource contribution that can flow from biofuels production to other enterprises as well as an offshoot of a possible link to the production of livestock products such as meat, egg and hide. It is worth noting that Fig. 3 does not show the complete list of external and internal inputs that can possibly feature in the link between biofuels production process and the production of food, fuel, feed and fibre crops.

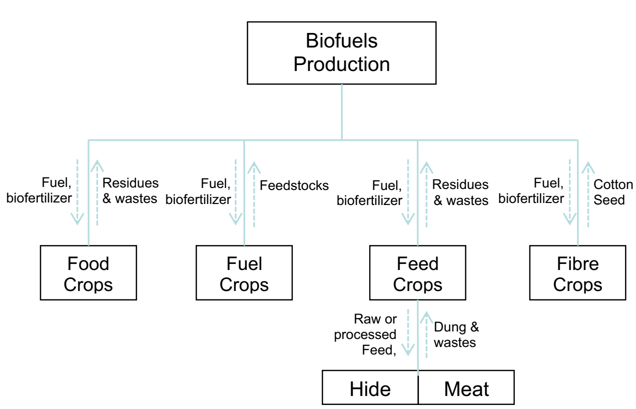

Fig. 3. Conceptual integration pathway between biofuels, food, fuel, feed and fibre crops production.

9. Conclusion

This paper attempted to explore issues that are necessary for ensuring the sustainability of the growing biofuels sector in Nigeria. The paper proposed a conceptual framework for integrating the food, fuel, feed and fibre objectives. The article explores the possibility of balancing the local production of the food, feed, fuel and fibre objectives through a more efficient use of the currently underutilized resources of land and water. Though it is expected that there might be a competition between objectives, it is anticipated that an efficient allocation of the required resources, designing an appropriate plan for implementing integration of production will help in increasing productivity per resource utilized. This paper is premised on the assumption that going by the current concerns for food, fuel, feed, and fibre, the adoption and development of biofuels in Nigeria creates a unique avenue for creating a link for balance between the objectives and attaining desired growth in each sub-sectors and increasing the contribution of agriculture to GDP, which will better reflect evenly distributed economic growth rather than a skewed growth accounted for by a few promising sub-sectors.

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